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(54) Title: METHOD OF UPDATING A CONTROL CHANNEL LIST IN MOBILE COMMUNICATIONS SYSTEM

(57) Abstract: A technique for allowing a mobile radio unit of a mobile radio communications system to find and synchronise to a signal of its radio system. The mobile unit stores a list of frequencies used by the radio system where it can expect to find radio system synchronization signals. To find a signal of the radio system, the mobile unit initially scans all the frequencies in its list to assess the signal level on each frequency, and to assess whether the signal on each frequency has particular characteristics, e.g. the phase shift characteristics, of a signal of the radio system. The probability that the signal has the correct signal characteristics is stored with the signal level and the frequencies in the list are then reordered according to the measured signal levels and the probability that the signals have the required particular signal characteristics, to provide a revised frequency order for the mobile unit to then attempt to synchronise to.

METHOD OF UPDATING A CONTROL CHANNEL LIST IN MOBILE COMMUNICATIONS SYSTEM

The present invention relates to mobile radio communications systems and in particular to a method of and an apparatus for enabling a mobile radio unit of a mobile radio communications system to find and acquire a radio channel for communicating with a base station of the mobile radio communications system.

As is known in the art, for a mobile radio unit of a mobile radio communications system to be able to communicate with the fixed radio network (and thereby operate in the radio system), the mobile radio unit must be tuned to a radio channel of a base station of the mobile radio system. This means that whenever a mobile radio unit first becomes active, or migrates into a new area, it must, before it can communicate with the radio system, identify and synchronise to a suitable base station radio channel.

Similarly, if it is necessary for a mobile radio unit to be handed over from a first base station to a second base station during an on-going call, the mobile radio unit must be able to identify and synchronise to a radio channel of the new base station.

To minimise any interruption in communication when a mobile radio unit needs to find the new base station, it is desirable for the mobile radio unit to be able to recognise and synchronise to the new base station radio channel as quickly as possible, particularly during a handover (as handover desirably occurs with the minimum possible interruption in communication).

To facilitate the identification of and subsequent synchronisation to a suitable base radio station channel, mobile radio units will typically, as is known in the art, store a list of radio frequencies used by base stations of the radio system, and, when it is

necessary to find a new radio channel, tune in turn to each frequency in the stored list and attempt to synchronise on each frequency until a suitable radio channel is found.

The channel synchronisation search typically comprises the mobile radio unit listening on the particular frequency for a limited period of time to try to detect special synchronisation signalling which should be present on the frequency if it is available and suitable for the mobile radio unit to use. If the mobile radio unit does not detect the synchronisation signalling during the waiting time period, the mobile radio unit will turn to another frequency on its list, and so on, until it succeeds in synchronising on a frequency with a suitable signal.

However, in many mobile radio systems, the synchronisation signals may only be broadcast at intervals. For example, synchronisation signals are broadcast at intervals of 235 ms in the GSM (Global System for Mobile communications) system. In the TETRA (TErrestrial Trunked RAdio) system, synchronisation signals may only be broadcast at intervals of up to 4 seconds.

The search waiting time period on each frequency must therefore be at least the expected interval between synchronisation signals to allow sufficient time for a synchronisation signal to be received, before trying another frequency. In practice, the waiting time will often be longer than a single synchronisation signal interval, as typically, sufficient time to receive two or three synchronisation signals is allowed on each frequency in order to, for example, reduce the effects of fading causing suitable synchronisation signals to be improperly received.

Thus, for example, to identify and synchronise on a good TETRA signal could take well over 1 minute if the mobile radio unit has just been switched on in a new

area and it has a list of, for example, sixty possible frequencies to search. Such delay in channel acquisition is undesirable, as it increases the interruption in communications when a new radio channel is required.

It is known therefore to modify the base station radio channel search process to try to reduce the possible delay in identifying and synchronising to a new base station radio channel.

For example, in some radio systems, including the TETRA system, the frequencies used by adjacent base stations may be broadcast to mobile radio units, so that the number of frequencies to be searched for a suitable radio signal when moving to an adjacent area can be reduced. However, even in that case, having to pause on each possible frequency for several seconds from even a reduced search list can still mean that it takes up to a minute to find a strong signal and synchronise to it.

Another common method of speeding up the scanning of potential frequencies in the frequency list is to tune to each of the frequencies for a relatively short period of time to measure the signal level on the frequency (but not necessarily long enough to receive a synchronisation signal). The mobile radio unit then records the signal level and moves on to the next frequency to be inspected. This process is typically repeated several times, as is known in the art, to build up a set of spaced signal level measurements for each frequency, which measurements are then, for example, averaged to give an overall signal level estimate for the frequency. When the mobile radio unit has been through its list of candidate frequencies a sufficient number of times, it ranks them in order of signal level and, starting with the frequency having the highest measured signal level, returns to the frequencies to listen for a longer period of time for synchronisation signals on each frequency in turn until it achieves

synchronisation.

This technique helps to reduce the radio channel acquisition time. However, the Applicants have recognised that it can still have problems. For example, frequencies on which there are strong interfering signals with relatively high signal levels will still tend to be placed at the top of the revised list of frequencies to be examined in detail following the initial faster frequency scan, even if those frequencies could in practice be unusable. Thus a mobile radio unit may still waste time trying to obtain synchronisation on an inappropriate signal before working on down its list to choose a compatible base station radio channel.

According to a first aspect of the present invention, there is provided a method of operating a mobile radio unit of a mobile radio communications system, in which radio system the mobile radio unit stores a list of target frequencies to scan for a suitable frequency for communicating with a base station of the radio system, the method comprising:

the mobile radio unit scanning each frequency in its list, and determining for each frequency the signal level of the signal on that frequency, and assessing for each frequency whether the signal on that frequency has a particular characteristic of the radio system;

the mobile radio unit then determining a revised frequency order on the basis of the determined signal levels and the characteristic assessments for each frequency; and

the mobile radio unit then attempting to synchronise to the frequencies in the revised frequency order in the order of the revised frequency order.

According to a second aspect of the present invention, there is provided a mobile radio unit for use in a mobile radio communications system, in which system plural frequencies are used for radio communications,

the mobile radio unit comprising:

means for storing a list of frequencies used by the radio system;

means for scanning each frequency in the stored list;

means for determining for each scanned frequency the signal level of the signal on that frequency;

means for assessing for each scanned frequency whether the signal on that frequency has a particular characteristic of the radio system;

means for determining a revised frequency order based on the determined signal levels of each frequency and the assessments of whether each frequency has the particular characteristic of the radio system; and

means for attempting to synchronise to the frequencies in the revised frequency order in the order of the revised frequency order.

In the present invention, as in the known frequency searching techniques, an initial scan of the frequency list stored by the mobile radio unit is carried out, but as well as determining the signal level of each frequency during the initial scan, an assessment of whether the signal on the particular frequency has a particular characteristic of the radio system is also made. The signal level and characteristic assessment results are then used together to derive a revised order in which to scan the frequencies for synchronisation signals.

The Applicants have recognised that many radio systems will have characteristic properties to their signals that can be relatively rapidly identified and will distinguish them from signals of other radio systems. Thus assessing whether the signal on each frequency has the relevant particular characteristic gives an assessment of the likelihood of the signal on that frequency being from the correct radio system. The assessment of whether the signal has the relevant

particular characteristic can also give a measure of how 'useful' the signal is likely to be, since, if the signal shows the relevant signal characteristic strongly, that would suggest that the signal is valid and useful.

Thus the assessment of whether the signal has the relevant particular characteristic can be used to place signals more likely to be from the correct radio system and more likely to be useable towards the top of the revised frequency list for the synchronisation scan so as to reduce the possibility of trying to synchronise to an alien or incompatible signal before more suitable signals are considered.

Thus the present invention provides a refined process for selecting those signals (i.e. frequencies) to attempt to synchronise to first, which can be used to improve the order in which the frequencies are scanned for synchronisation to scan what appear to be more suitable signals first and thereby to reduce the possibility of wasting time trying to synchronise on incompatible signals and to improve the speed at which a new suitable frequency (and therefore base station) is acquired.

The initial faster frequency scan can be carried out as desired. For example, the mobile radio unit could pause once on each frequency in its list in turn to carry out the signal assessment. However, the initial scan is preferably carried out by the mobile unit carrying out plural measurements at spaced intervals on each frequency, preferably by returning to each frequency to be scanned at spaced intervals during the initial scan, e.g. such that an assessment is carried out on each frequency in turn and the cycle of measurements over the different frequencies is repeated several (i.e. two or more) times. This method ensures that successively assessed signal samples on the same frequency are relatively well-spaced in time, thereby

providing better averaging of the measurements, and helping to ensure that not all measurements on a frequency are made during the same fade (unless the receiver is stationary).

The frequency list to be scanned could be the list of all frequencies used by the radio system, or it could be a reduced list, for example of only those frequencies known to be in use in the particular area, or in adjacent cells, as is known in the art.

The signal level for each frequency can be estimated as desired and in any suitable manner known in the art.

The characteristic of the radio system for which the signals are assessed can be selected as desired. It should be a characteristic of the system that can be used to distinguish it from other radio systems. It should also not take too long to assess and preferably can be assessed in the same time that it takes to determine the signal level, i.e. such that the characteristic assessment does not extend the duration of the initial faster frequency scan. More than one characteristic can be considered if desired. Preferably, the characteristic of the signal is assessed, and the observed signal characteristics are then compared with the expected characteristics for the radio system, e.g. to see how well they correspond, to assess whether the signal has the required characteristic.

In a particularly preferred embodiment, the signal characteristic assessment comprises assessing whether the signal has a characteristic of the radio modulation scheme used in the radio system. The Applicants have recognised that many radio systems use particular radio modulation schemes which modulation schemes have particular characteristics that can be assessed relatively quickly. Thus considering the modulation of the signal can give a good assessment of its

suitability.

For example, in the TETRA system, π/4 DQPSK (π/4 Differential Quaternary Phase-Shift Keying) modulation is employed. This form of modulation has the particular characteristic that there is a +/- π/4 or +/- 3π/4 radians phase shift between each transmitted symbol (there is never a phase shift of zero radians). The GSM system, on the other hand, uses GMSK (Gaussian Minimum Shift Keying) modulation, which employs phase shifts of +/- π/2 radians relative to a steady RF (radio frequency) carrier. In this case a phase shift of zero is permitted, so a characteristic of GMSK modulation is the presence of phase shifts of either zero radians or π radians between successive symbols (more specifically a +π is always followed by either 0 or -π, and no +π may follow +π and any subsequent 0's until a -π has occurred; a -π is always followed by either 0 or +π, and no -π may follow -π and any subsequent 0's until a +π has occurred). Other modulation schemes (such as 16QAM) have other characteristics which can be detected in an appropriate manner. For example, a four-level FM modulation scheme will exhibit FM modulation with transitions between four different modulating frequencies, and so will show characteristic frequency shifts.

Thus in a particularly preferred embodiment, the assessment of whether the signal on a particular frequency has the particular characteristic of the radio system comprises an assessment of whether the signal exhibits the particular phase or frequency shift characteristics of the radio system's modulation scheme. This could be assessed by analysing the phase or frequency shifts between successive selected samples or portions, e.g. symbols, in the signal on the frequency and comparing the observed phase or frequency shifts with the expected phase or frequency shifts for the wanted modulation scheme, e.g. to see how well they

correspond, to assess whether the signal carries the required form of modulation.

The analysis of the phase or frequency shifts can be carried out as desired and should be carried out at the same time as the signal level determination is carried out. Thus, in a TETRA system, for example, during the, say, 5 ms used to measure and average the signal level, the phase shifts between each successive symbol received during that period could be measured. Similarly where a frequency is assessed several times in the initial scan, by, e.g. measuring the signal level and modulation characteristics for a shorter time, e.g. 1 ms, and then changing frequency and repeating the cycle, e.g. 5 times and averaging the five measurements, the phase shifts between each successive symbol received during each scanning period could be measured. In the TETRA system, each symbol has a duration of 56 microseconds, so in the TETRA system up to 90 symbol phase shifts could be examined in the 5 ms period (or up to 18 in a 1 ms period).

The measured phase or frequency shifts can be used as desired to assess whether the signal has the particular characteristic. For example, the actual values of the phase shifts could be considered. The assessment could, for example, comprise looking at whether appropriate values and/or sequences of phase or frequency shifts are observed.

For example, if a TETRA signal was being sought, but random phase shifts are detected, then that would indicate a very poor TETRA signal. If phase shifts close to 0 or $\pi/2$ were prevalent, that would indicate a strong interfering signal using a different modulation scheme.

In another arrangement the measured phase shifts for the symbols could be mapped to a common (e.g. the first) quadrant (i.e. have their modulation induced phase differences removed) to obtain a mean phase shift

value and that value compared with the expected value for the modulation scheme used by the radio system. The variation in the values could also be considered.

In a particularly preferred embodiment, the assessment of whether or not the scanned signal has the particular characteristic comprises allocating a probability that the signal has that characteristic based on the assessment of the signal. Preferably three levels of relative probability, low, medium and high, are used. Thus preferably the fit of the candidate signal to the desired characteristic is measured on a probability scale and the probability of a match, e.g. the probability that it carries the required form of modulation, recorded. For example, the deviation of the mean phase or frequency shift from the expected value if the signal were to carry the correct form of modulation and/or the proportion of measured phase or frequency shift values having the value of the wanted modulation scheme, could be used to classify how likely the signal is to be from the correct radio system.

The reordering of the list of frequencies after the initial faster scan has been completed can be carried out as desired, based on the determined signal levels and radio system characteristic assessments.

The Applicants have recognised that a valid but weak signal will tend to exhibit a low to medium probability of being valid for the radio system (since weak signals will tend to suffer from much multipath distortion and this will introduce errors into the signal), but a higher signal level, valid signal, will have a higher probability. On the other hand, a strong signal showing a low probability of being valid can reasonably be rejected.

Thus in a particularly preferred embodiment the frequencies having signals having a high probability of being valid (i.e. assessed to be likely to have the particular characteristic) are considered first,

preferably in signal level order (highest first), and so on, with the signals having the lowest probability of being valid being considered last. In such an arrangement, the mobile radio unit will attempt to synchronise to signals having a higher signal level and a good assessment that they have the particular characteristic first, and only after synchronisation to those signals has failed will the mobile radio unit then attempt to synchronise on signals assessed to have a lower probability of being valid.

The revised frequency order which is used for the synchronisation scan can include all the frequencies in the initial faster frequency scan list, but this is not essential and it could include less frequencies. For example, in a preferred embodiment, signals found to have an undesirably low signal level are not included in the synchronisation scan. This can be achieved by using a threshold signal level to eliminate signals of undesirably low signal level from the synchronisation scan. Similarly, signals having less than a given probability of having the correct radio system characteristic could be eliminated from and not included in the revised synchronisation scan frequency order list.

The synchronisation scan should typically be stopped once the mobile unit finds a suitable frequency to synchronise to. If the mobile unit scans all the frequencies in the revised frequency order list in turn without finding a suitable signal, it could stop its synchronisation scan then (and, for example, inform the user accordingly), or, for example, repeat the scan (for, e.g., up to a predetermined number of times) before finally determining that synchronisation is not possible.

In a particularly preferred embodiment of the present invention, during the synchronisation scan when the mobile radio unit is waiting for a synchronisation

signal and attempting to synchronise to each frequency, the mobile radio unit preferably also carries out an assessment of whether the signal it is attempting to synchronise to does have the particular characteristic of the radio system, i.e. does belong to its radio system, and interrupts and aborts its wait and synchronisation attempt on that frequency, and switches onto the next frequency in its list, if it determines that the signal does not have the particular characteristics (i.e. does not belong to its radio system), e.g. it determines that there is greater than a particular probability that the signal does not have the particular characteristic. This allows the radio unit to abort earlier a synchronisation attempt on an unsuitable frequency. This arrangement may be advantageous, because the pause on a given frequency when attempting to synchronise is longer than the time taken to assess each signal during the initial faster frequency scan, and thus a more reliable signal characteristic assessment may be able to be made, as, e.g. the mobile radio unit will have longer to integrate the phase shifts between symbols, than during the initial faster frequency scan.

It is believed that using an assessment of the validity of a radio signal to abort a synchronisation attempt is new and useful in its own right. Thus, according to a third aspect of the present invention, there is provided a method of synchronising a mobile radio unit of a mobile radio communications system to a radio channel of the system, the method comprising:

the mobile radio unit scanning and attempting to synchronise to each frequency on a stored list of frequencies used by the radio system in turn;

the mobile radio unit while it is waiting on a particular frequency for synchronisation signals to attempt to synchronise to the frequency, assessing whether the signal on the frequency has a particular

characteristic of the radio system; and

the mobile radio unit aborting its wait on the frequency and tuning to a new frequency before the synchronisation attempt on the frequency is completed if it determines that the signal on that frequency does not have the particular characteristic.

According to a fourth aspect of the present invention, there is provided a mobile radio unit of a mobile radio communications system, the mobile radio unit comprising:

means for scanning and attempting to synchronise to each frequency on a stored list of frequencies used by the radio system in turn;

means for, while the mobile radio unit is waiting on a particular frequency for synchronisation signals to attempt to synchronise to the frequency, assessing whether the signal on the frequency has a particular characteristic of the radio system; and

means for aborting its wait on the frequency and tuning to a new frequency before the synchronisation attempt on the frequency is completed if it determines that the signal on that frequency does not have the particular characteristic.

Again, the assessment of whether the radio signal has a particular characteristic of the radio system is preferably based on assessing whether or not it has a characteristic of the radio modulation scheme used by the radio system.

Although the present invention has been described above with regard to the synchronisation scan operation of a mobile radio unit seeking a radio channel, it is believed that the idea of assessing whether a radio signal on a given frequency has a particular characteristic of a given radio system may be useful in other circumstances as well. For example, in some non-trunked radio systems a mobile radio unit may need to establish that a radio frequency is available for use,

i.e. that there is no signal from another radio unit of the same radio system present on the frequency, before it can seize the frequency for its use. For example, in TETRA direct mode, a new transmitter is not permitted to start using a radio channel (frequency) until it has verified that there is not a TETRA signal already present above some low signal level threshold, i.e. the channel is "empty". Such assessment could be carried out by assessing whether there is a signal on the frequency having the characteristics, e.g. modulation, of the particular radio system.

Thus there may be situations where a mobile radio unit needs to be able to confirm the absence of a particular type of signal, and it is believed that the technique of the present invention of assessing whether the signal on a frequency has a particular characteristic of a radio system could be used advantageously for such verification.

Thus, according to a fifth aspect of the present invention, there is provided a method of operating a mobile radio unit of a mobile radio communications system, the method comprising the mobile radio unit:

assessing whether the signal on a particular frequency has a particular characteristic of the radio system; and

making a determination as to whether or not the frequency already carries a signal of the radio system based on the characteristic assessment for the frequency.

According to a sixth aspect of the present invention, there is provided a mobile radio unit for a mobile radio communications system, the mobile radio unit comprising:

means for assessing whether the signal on a particular frequency has a particular characteristic of the radio system; and

means for making a determination as to whether or

not the frequency already carries a signal of the radio system based on the characteristic assessment for the frequency.

In these aspects of the present invention, the mobile radio unit preferably determines whether or not to perform an action in relation to the particular radio frequency, such as, for example, transmitting on the frequency or attempting to synchronise on the frequency, on the basis of the characteristic assessment for the frequency.

These aspects of the present invention can include, appropriately, any or all of the preferred and optional features discussed above in relation to the other aspects of the invention. Thus, the assessment of whether the signal has the relevant particular characteristic is preferably based on assessing whether or not it has a characteristic of the radio modulation scheme, such as particular frequency or phase shifts, used by the radio system.

In this arrangement where appropriate, the mobile radio unit could again search or scan through a list of frequencies used by the system, and carry out an assessment on each frequency, for example until such time as it finds a free frequency for its use.

The methods in accordance with the present invention may be implemented at least partially using software e.g. computer programs. It will thus be seen that when viewed from a further aspect the present invention provides computer software specifically adapted to carry out the methods hereinabove described when installed on data processing means, and a computer program element comprising computer software code portions for performing the methods hereinabove described when installed on data processing means. The invention also extends to a computer software carrier comprising such software which when used to operate a mobile radio unit or a radio system comprising a digital

computer causes in conjunction with said computer said radio unit or system to carry out the steps of the method of the present invention. Such a computer software carrier could be a physical storage medium such as a ROM chip, CD ROM or disk, or could be a signal such as an electronic signal over wires, an optical signal or a radio signal such as to a satellite or the like.

It will further be appreciated that not all steps of the method of the invention need be carried out by computer software and thus from a further broad aspect the present invention provides computer software and such software installed on a computer software carrier for carrying out at least one of the steps of the methods set out hereinabove.

A number of preferred embodiments of the present invention will now be described by way of example only.

The embodiments will be described with reference to the TETRA system, although as will be appreciated from the above, the invention is also applicable to other mobile radio communications systems, such as the GSM system.

An example of the operation of a mobile radio unit in accordance with the present invention when it is first switched on (i.e. of cold synchronisation) will now be considered.

For this example, we will suppose that the mobile radio unit stores a list of 60 frequencies where it can expect to find system synchronization signals, and requires 5 ms to tune its synthesizer to one of these frequencies, and a further 5 ms to measure the signal level on that frequency. We will further suppose that considering the TETRA specification, base stations of the radio system transmit synchronization bursts (signals) at 1 second intervals on their particular frequency, but that each synchronisation burst is in a different one of the 4 TETRA timeslots, so that it takes 4 seconds for a synchronization burst to be repeated on

a particular timeslot.

When the mobile radio unit has just been switched on, its first task is to locate a TETRA radio system as quickly as possible. In the basic prior art system discussed above, the mobile unit would tune to each frequency in its stored list in turn and monitor each frequency for a minimum of 1 second, to be sure of listening at the time a base station would be transmitting a synchronization burst. The search time for the 60 frequencies will be of the order of 1 minute (but there is a 1 in 1080 chance that the search time will be only 15 ms and a 1 in 60 chance that the search time will be 1 second).

Now consider a more sophisticated mobile radio unit, operating the prior art technique of initially scanning all 60 channels in its list to build up a table of signal levels before attempting synchronisation. A fast scan duration of 5 seconds (which is a typical time selected for such a frequency scan, being a reasonable compromise between the need to sample signals over as great a distance as possible to help ensure sample de-correlation and the desire not to "waste" too much time doing the scan) will be assumed. At 5 ms tuning time and 5 ms signal level measurement time, this fast scan duration will give 8 spaced signal samples per frequency, which is a reasonable number. Having ordered the frequencies in order of signal level the mobile radio unit then returns to each frequency in the revised order to attempt synchronisation on that frequency. In the absence of interfering signals it should be able to synchronize after a further 1 second. Thus in this case the maximum time to synchronize should be 6 seconds (5 seconds to scan plus 1 second to synchronise), but there is a 1 in 18 chance of synchronizing in 5.015 seconds. It would not be possible to synchronize from cold faster than this.

However, as discussed previously, interfering

signals will reduce the benefits of this method of searching. The interference could be accidental (e.g. vehicle ignition pulses or a nearby desktop or laptop computer), or it could be intentional transmissions from another system using a different modulation scheme. The latter is a potential problem for TETRA systems, which share frequencies with military users.

In the case where the two strongest signals turn out to be interference, the mobile radio unit in this example would still attempt to synchronise to those unsuitable signals first, thereby introducing a further delay of 8 seconds (it taking 4 seconds to reject each interference frequency). In this case the cold synchronization time would be at least 13.015 seconds (5 seconds to scan, 8 seconds to reject the two interference frequencies and 0.015 seconds to synchronise to the third frequency tested), but more probably 14 seconds.

Now consider a mobile radio unit which employs the method of the present invention. It first performs a fast frequency scan in which it dwells on each frequency (at several spaced intervals) for 5 ms to record the average signal level, and at the same time records the digital samples received by its demodulator and using a digital signal processor, examines the recorded digital samples, looking for evidence of $\pi/4$ and $3\pi/4$, but never zero, phase shifts at the expected symbol rate. The probability that this has been detected is stored with the averaged signal level. (This can be done while the mobile radio unit is tuning to the next frequency in the list.) This fast frequency scan would again, as discussed above, typically be arranged to be carried out over a period of the order of 5 seconds to try to ensure sufficient spaced samples for each frequency. After this initial "fast" frequency scan, the scanned frequencies are then ordered according to their averaged signal levels and the probability that their signal has

the required particular modulation characteristics, to provide a revised scanning order list of the frequencies in the list.

In this case, if the two strongest signals are again interference, those frequencies will have strong signal levels, but low probabilities of having the particular modulation characteristic. Thus when the mobile radio unit has completed its fast scan, it will place those two strongest signals low in its revised frequency scanning order as they are recorded as having a low probability of bearing TETRA modulation. Instead, the mobile radio unit will tune straight to the third strongest signal, which, for example, has been recorded as having a medium or high probability of carrying TETRA modulation. Thus the mobile unit's cold synchronization delay would remain in the region of 5.015 to 6 seconds (i.e. 5 seconds to scan and 1 second to synchronise).

We will now consider what happens when a mobile radio unit needs to identify a new base station for handover, i.e. while it is engaged in a call.

In the first, basic prior art technique, discussed above, the mobile radio unit has to listen for each potential new base station in turn. The base stations' TDMA frame structures in TETRA are not synchronized, so in order to find a synchronization burst on an adjacent cell, the mobile station retunes its synthesizer between reception slots. This allows it to look for approximately two time slots for a possible synchronization burst on an adjacent cell before having to retune back to the serving cell frequency, and this can be done in each frame.

As the synchronization bursts cycle through the time slots the mobile radio unit will have to wait up to 4 seconds to ensure that a synchronization opportunity has occurred, before choosing a new frequency. At this rate, the mobile radio unit could take up to 4 minutes to synchronize to a new base station, by which time the

call would most probably have been lost, even if the frequencies of the six adjacent cells had been broadcast to allow a reduced frequency list to be searched.

The more sophisticated prior art mobile radio unit of the previous example could attempt to keep its table of signal strengths always up to date. It might even attempt to store synchronization data on the best alternative base station, so that handover can be achieved without any searching delays. However, suppose that for some reason the signal strength table needs to be renewed (as could happen if the mobile radio unit has rounded a bend in a high-sided valley, or entered a new street in a high rise urban environment). As before, the mobile radio unit performs its fast scan of signal levels in 5 s, and then searches each entry in the list in sequence. Considering again the case where the two strongest signals are in fact interference, the mobile radio unit would have to pause on the unsuitable first 2 frequencies for at least 4 seconds each as before (or 8 seconds each, if giving the receiver 'two bites at the cherry' as is usual, to reduce the effects of fading). After pausing a further 4 (or 8) seconds on the third frequency in the list, it achieves synchronization, after a delay of between 13 and 17 seconds (or 21 and 29 seconds in a faded channel). The call might have been lost during this interval.

If the mobile radio unit employs the method of the present invention, it will in this case rank the two strongest signals quite low, as shown in the previous example, and attempt to synchronize to the third strongest signal (i.e. the strongest signal showing a high probability of having the right modulation scheme). The synchronization delay is now reduced to between 5 and 9 seconds (or 13 seconds in a faded channel).

It can be seen from the above that the mobile radio unit operating in accordance with the present invention uses both the signal level and radio system

characteristics derived during the initial faster frequency scan when deciding which frequencies to attempt to synchronise to. It in effect supplements the signal level information determined during the initial faster frequency scan with data indicating the probability that the corresponding signal is useful. This improves the ranking of the signals to then attempt to synchronise to, and thus reduces the probability of wasting time trying to synchronise on incompatible signals.

Claims

1. A method of operating a mobile radio unit of a mobile radio communications system, in which radio system the mobile radio unit stores a list of target frequencies to scan for a suitable frequency for communicating with a base station of the radio system, the method comprising:

the mobile radio unit scanning each frequency in its list, and determining for each frequency the signal level of the signal on that frequency, and assessing for each frequency whether the signal on that frequency has a particular characteristic of the radio system;

the mobile radio unit then determining a revised frequency order on the basis of the determined signal levels and the characteristic assessments for each frequency; and

the mobile radio unit then attempting to synchronise to the frequencies in the revised frequency order in the order of the revised frequency order.

2. The method of claim 1, wherein the initial scan of each frequency in the list comprises the mobile unit taking signal samples at spaced intervals on each frequency.

3. The method of claim 1 or 2, wherein the signal characteristic assessment comprises assessing whether the signal has a characteristic of the radio modulation scheme used in the radio system.

4. The method of claim 3, wherein the signal characteristic assessment comprises assessing whether the signal exhibits particular phase or frequency shift characteristics of the radio system's modulation scheme.

5. The method of claim 4, wherein the step of

assessing whether the signal exhibits particular phase or frequency shift characteristics of the radio system's modulation scheme comprises analysing the phase or frequency shifts between successive selected samples or portions in the signal on the frequency and comparing the observed phase or frequency shifts with the expected phase or frequency shifts for the wanted modulation scheme.

6. The method of claim 4 or 5, comprising using the deviation of the mean observed phase or frequency shift for the signal being assessed from the expected value if the signal were to carry the correct form of modulation and/or using the proportion of observed phase or frequency shift values having the value of the wanted modulation scheme, to classify how likely the signal is to be from the correct radio system.

7. The method of any one of the preceding claims, wherein the assessment of whether or not the scanned signal has the particular characteristic comprises allocating a probability that the signal has that characteristic based on the assessment of the signal.

8. The method of any one of the preceding claims, wherein the revised frequency order is determined such that frequencies having signals assessed to be most likely to have the particular characteristic are attempted to be synchronised to first, and the signals assessed to be least likely to have the particular characteristic are attempted to be synchronised to last.

9. The method of claim 8, wherein the revised frequency order is further arranged in signal level order.

10. The method of any one of the preceding claims, further comprising eliminating signals having a signal level less than a threshold signal level from the revised frequency order.

11. The method of any one of the preceding claims, comprising: the mobile radio unit, during the synchronisation scan when the mobile radio unit is attempting to synchronise to each frequency and is waiting for a synchronisation signal, carrying out an assessment of whether the signal it is attempting to synchronise to does have the particular characteristic of the radio system, and interrupting and aborting its wait and synchronisation attempt on that frequency, and switching onto the next frequency in the list, if it determines that the signal does not have the particular characteristic.

12. A method of synchronising a mobile radio unit of a mobile radio communications system to a radio channel of the system, the method comprising:

the mobile radio unit scanning and attempting to synchronise to each frequency on a stored list of frequencies used by the radio system in turn;

the mobile radio unit while it is waiting on a particular frequency for synchronisation signals to attempt to synchronise to the frequency, assessing whether the signal on the frequency has a particular characteristic of the radio system; and

the mobile radio unit aborting its wait on the particular frequency and tuning to a new frequency before the synchronisation attempt on the particular frequency is completed if it determines that the signal on the particular frequency does not have the particular characteristic.

13. A method of operating a mobile radio unit of a mobile radio communications system, the method comprising the mobile radio unit:

assessing whether the signal on a particular frequency has a particular characteristic of the radio system; and

making a determination as to whether or not the frequency already carries a signal of the radio system based on the characteristic assessment for the frequency.

14. A mobile radio unit for use in a mobile radio communications system, in which system plural frequencies are used for radio communications, the mobile radio unit comprising:

means for storing a list of frequencies used by the radio system;

means for scanning each frequency in the stored list;

means for determining for each scanned frequency the signal level of the signal on that frequency;

means for assessing for each scanned frequency whether the signal on that frequency has a particular characteristic of the radio system;

means for determining a revised frequency order based on the determined signal levels of each frequency and the assessments of whether each frequency has the particular characteristic of the radio system; and

means for attempting to synchronise to the frequencies in the revised frequency order in the order of the revised frequency order.

15. The mobile unit of claim 14, wherein the signal characteristic assessment means comprises means for assessing whether the signal has a characteristic of the radio modulation scheme used in the radio system.

16. The mobile unit of claim 15, wherein the signal characteristic assessment means comprises means for assessing whether the signal exhibits particular phase or frequency shift characteristics of the radio system's modulation scheme.

17. The mobile unit of claim 16, comprising means for classifying how likely the signal is to be from the correct radio system on the basis of the deviation of the mean observed phase or frequency shift for the signal being assessed from the expected value if the signal were to carry the correct form of modulation and/or on the basis of the proportion of measured phase or frequency shift values having the value of the wanted modulation scheme.

18. The mobile unit of any one of claims 14 to 17, wherein the revised frequency order determining means is arranged to determine the revised frequency order such that frequencies having signals assessed to be most likely to have the particular characteristic are attempted to be synchronised to first, and signals assessed to be least likely to have the particular characteristic are attempted to be synchronised to last.

19. The mobile unit of claim 18, wherein the revised frequency order determining means is further arranged to determine the revised frequency order in signal level order.

20. The mobile unit of any one of claims 14 to 19, wherein the revised frequency order determining means is arranged to eliminate signals having a signal level less than a threshold signal level from the revised frequency order.

21. The mobile unit of any one of claims 14 to 20,

comprising

means for, during the synchronisation scan when the mobile radio unit is attempting to synchronise to each frequency, while the mobile unit is waiting for synchronisation signals, assessing whether the signal it is attempting to synchronise to does have the particular characteristic of the radio system; and

means for interrupting and aborting the wait and synchronisation attempt on that frequency, and for switching onto the next frequency in the list, if it is determined that the signal does not have the particular characteristic.

22. A mobile radio unit of a mobile radio communications system, the mobile radio unit comprising:

means for scanning and attempting to synchronise to each frequency on a stored list of frequencies used by the radio system in turn;

means for, while the mobile radio unit is waiting on a particular frequency for synchronisation signals to attempt to synchronise to the frequency, assessing whether the signal on the frequency has a particular characteristic of the radio system; and

means for aborting the wait on the particular frequency and tuning to a new frequency before the synchronisation attempt on the particular frequency is completed if it is determined that the signal on the particular frequency does not have the particular characteristic.

23. A mobile radio unit for a mobile radio communications system, the mobile radio unit comprising:

means for assessing whether the signal on a particular frequency has a particular characteristic of the radio system; and

means for making a determination as to whether or not the frequency already carries a signal of the radio

system based on the characteristic assessment for the frequency.

24. A computer program element comprising computer software code portions for performing the method of any one of claims 1 to 13 when installed on data processing means.

25. A method of operating a mobile radio unit of a mobile radio communications system substantially as hereinbefore described.

26. A mobile radio unit for use in a mobile radio communications system substantially as hereinbefore described.

Inte onal Application No
PCT/GB 00/04080

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H04Q7/32

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H04Q

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, WPI Data, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
28 February 2001	07/03/2001

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Roberti, V

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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INTERNATIONAL SEARCH REPORT

International Application No
PCT/US2004/015578

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H04L12/28 H04Q7/32 G06K17/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H04L H04Q G06K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, WPI Data, PAJ, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	LOPEZ PEREZ M C

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